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CARBONIFEROUS FORMATIONS OF NEW MEXICO

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Several features contribute to make the Carboniferous section of New Mexico the most noteworthy of the American continent. Its enormous thickness, the strictly marine nature of its sediments which constitute it the most imposing limestone plate among the known formations of the country, the feeble development of extensive shale beds so familiar elsewhere, the total absence of workable coal-beds which are the one feature of all others that is usually characteristic wherever the rocks of this age are found, the existence of a number of great planes of unconformity clearly indicating enormous erosion intervals, and the great abundance of organic remains, are some of the more salient points contrasting the Carboniferous of New Mexico with the sections of the same system elsewhere.

It has been unfortunate that the notes which have been made during the past half-century upon the Carboniferous rocks of the southwestern United States have been so meager, and so disconnected, and the publications in which they have appeared so widely scattered. From the literature alone, practically no correlation of separated sections has been possible. Confronted with these exceptional conditions, it soon became one of the main objects in the course of the geological survey of the New Mexican region to examine not only all of the Carboniferous exposures, as far as possible, and to correlate them in the field, but from the point of vantage thus gained to connect with these broader observations the fragmentary notes previously published.

The great thickness of the "Upper Carboniferous limestones" of the southern Rocky Mountain region has always been a matter of comment among all those who have traversed this part of the country. Few of these persons have ventured to put the measurement of these great limestones above about 2,000 feet. That the connected section of the Carboniferous strata as represented within the boundaries of New Mexico, indicated a thickness which was

actually so enormous as it is, and as the recent measurements clearly show, was never thought of. This maximum thickness is now known to exceed 6,000 feet. Six great and important series have been differentiated. As now recognized, they are, with their respective thicknesses, as follows:

<i>Unconformity</i>	
Cimarronian sandstones and shales	1,000 feet
<i>Unconformity</i>	
Guadaloupan limestones	2,500 "
Maderan limestones	700 "
Manzanan limestones	1,300 "
<i>Unconformity</i>	
Ladronesian shales and sandstones	100. "
<i>Unconformity</i>	
Socorran limestones	500 "
<i>Unconformity</i>	

Of these, one series is Early Carboniferous, and is found only south of the central portion of the state; two are of Mid-Carboniferous age; and three belong to the Late Carboniferous.

With the schematic, or standard, section of the American Carboniferous series, as represented in the Continental Interior province, in Missouri and Kansas (II), may be paralleled the section of the Southwestern province represented by New Mexico (I), and also the eastern section of Pennsylvania (III), as usually given.

	TIME DIVISIONS	PROVINCIAL SERIES		
		I	II	III
CARBONIFEROUS	Late	Cimarronian Guadaloupan Maderan	Cimarronian Wanting Oklahoman	Wanting Wanting Permian
	Mid	Manzanan Wanting Ladronesian	Missourian DesMoines Arkansan }	Pennsylvanian
	Early	Socorran	Mississippian	Pocono

Comparing in a general way the New Mexican succession of the Carboniferous formations with that of the Upper Mississippi valley, there is at once noticeable in the first-mentioned section a rela-

tively much poorer representation of the Early Carboniferous sediments, an almost entire absence of the early Mid-Carboniferous shales, a very much greater development of middle and late Mid-Carboniferous marine beds, and a very great expansion of the middle Late Carboniferous marine deposits, while the sediments of the closing period are very much the same in both.

The thicknesses of the various formations are readily determined, usually in single unobscured vertical sections displayed in the fault scarps of the block-mountains which rise 3,000 to 5,000 feet above the plains at their bases, giving continuous outcrops that for unbroken extent are nowhere in the world surpassed.

The marine nature of practically the entire Carboniferous sequence, as represented in New Mexico, contrasts it strongly with the sections of the central and eastern United States. The main body of limestones composing the Manzanan and Maderan series were early recognized by government explorers as "Upper Carboniferous limestones." These two series and some other beds, taken together, have more recently, especially in the Grand Canyon district, eastern Arizona, and western New Mexico, generally gone under the title of the Aubrey limestone; and in western Texas, under the vaguely defined name of the Hueco limestone. Over the greater part of all of these regions the formation passing under a single title is easily separable into three or four distinct formations having serial rank, and each again is locally subdivisible.

The general absence of shales and coal-beds in the Carboniferous formations of the New Mexican region is one of its most striking features, particularly to one who has been accustomed to the great beds of shales, shaly sandstones, bituminous beds, and coals of the East. The horizons at which these deposits could be naturally expected are immediately beneath the great limestone plate having the Manzanan series for its base. There is, however, at this stratigraphic level a great plane of unconformity which is of very wide extent, and which represents a profound erosion interval.

If extensive shales ever existed here, and they evidently have, they have been almost entirely swept away. That there were once important coal-measures deposited on this old erosion surface is

amply demonstrated by isolated deposits which still remain in protected localities, accidentally preserved through dropped fault-blocks. For example, near Socorro there have been recently discovered several such remnants of coal-bearing shales, both in the Sierra Ladrones and to the east of the town. The deposits of the latter rest in marked unconformity upon the rocks beneath, and appear to have unconformable relationships with the strata above. Although only about 100 feet of these shales now remain in the locality mentioned, the recognition of their presence, their character, and their location is very likely to lead soon to discoveries of very much greater developments. For this reason, and on account of the important period which the deposits manifestly represent, they have been called the Ladronesian series.

The principal or great planes of unconformity which have been made out are five in number. They all represent great erosion intervals. The only similar phenomenon in the Mississippi valley at all comparable to any one of them is the unconformity at the base of the Des Moines series, in Iowa, Illinois, and Missouri; and it is now known that during this interval the entire Arkan-san series of shales, over 10,000 feet in thickness, was laid down. With two exceptions, all of the six series recognized are separated by great unconformities, and there are also unconformities at the base and at the top of the Carboniferous sequence. Besides these five unconformities of wide extent, there are a number of local phenomena of similar character, the exact magnitude of which is as yet not fully determined.

The character and location of some of these unconformity horizons in the New Mexican field suggest their presence in the Kansas, Oklahoma, and Texas sections where they have not before been suspected. And this accounts for some hitherto inexplicable observations that have been made in those states.

Organic remains of the entire Carboniferous section are, with few exceptions, strictly marine types. They are abundant throughout the whole sequence, except perhaps at the very top. In most localities where the rocks are well exposed fossils are as plentiful as they are in the more familiar sections of eastern Kansas. Some of the faunas are totally unlike anything described from other parts

of the American continent. Their definition, range, distribution, and comparison with those of other provinces promise interesting and instructive results. In the New Mexican province a most inviting and unique field awaits students of Carboniferous life.

Enough is now known of the fossils to enable their general affinities to be made out with reasonable certainty. Much that is new is to be found among them. The careful determination of the range and distribution of the various faunas and faunules is necessary before exact comparisons can be made with those of other provinces, and correlation made according to biotic methods alone.

The serial subdivisions of the New Mexican Carboniferous succession is based partly upon biologic data, but largely upon direct stratigraphic grounds. Correlation with the Kansas section has been mainly by organic content, and secondarily by general formational relationships. The correspondence of the two perfectly independent records is close to a degree that is quite remarkable.

As already intimated, six distinct and easily recognizable subdivisions of the great succession of strata have been defined. Taxonomically they hold the rank of series. Special mention of the numerous minor formations which go to make up these series need not be made at this time. However, the several series may be briefly characterized.

The basal series to which the title Socorran has been given comprises all of the Early Carboniferous sediments in the Southwestern province. It corresponds to the original Mississippian series of the Continental Interior province, though it manifestly does not include so much. According to present faunal and stratigraphical evidence, its equivalent in the Upper Mississippi valley is the Chouteau and Burlington limestones. A prolific Lower Burlington fauna, including most of the most typical crinoids, is found at Lake Valley. Nothing higher than the strata containing the Lower Burlington fauna has yet been found in this region. Whether this later part is present and concealed, or actually absent altogether, cannot be at present stated. A profound erosion plane bevels off all known Early Carboniferous strata; hence it is quite probable that considerable more of the basal portion of the general section will sooner or later be brought to light in this region.

Ladronesian is a title applied to the only coal-bearing formation of the entire section under consideration. This series now exists only in remnants of a formation that was once evidently quite extensive. It consists chiefly of shales and sandstones with thin coal-seams. The formation rests unconformably upon the rocks beneath. Profound Carboniferous erosion has all but completely obliterated all evidences of its existence. The shales carry interesting coal plants, chiefly of lepidodendrid types. There is but small doubt that the formation is the representative of the Arkansan series of the Ozark region.

Resting unconformably upon all rocks beneath is the great blue and gray limestone plate which is that portion of the Carboniferous section with which most travelers have come into contact, and which is most familiar. Farther west the lower portions have been called the Aubrey limestones. To the south the major portion is known as the Hueco limestone. The upper part of this unbroken limestone sequence is absent over all of Arizona and New Mexico, except in the extreme southern part of the latter. Faunally, as well as stratigraphically and lithologically, the great plate is separable into three distinct sections. These three formations, which have serial rank, are the Manzanan, the Maderan, and the Guadalupean series.

The Manzanan series is composed chiefly of massive blue and gray limestones with some thin gray shale layers. The fossils are essentially those which characterize the Missourian series of eastern Kansas. In the northern half of New Mexico this formation reclines directly upon the eroded surface of the Aechæzoic and Proterozoic crystallines.

Above the Manzanan series, and apparently continuous with it, is a lithologically similar formation, though it is more of a gray color, and often having dark layers intercalated. It is termed the Maderan series; and it carries the so-called Lower Permian fauna of Kansas. It is paralleled approximately with the Oklahoman part of that succession. This hard limestone formation is the rock-floor over a considerable portion of northern Arizona and west-central New Mexican region. It is this formation that manifestly constitutes the chief part of the Hueco formation of Trans-Pecos Texas.

The Guadaloupan series is unique. In all the American continent there is no formation with which it may be compared, or with which it may be geologically correlated. At the typical locality it consists of a thick sandstone at the base, surmounted by over 1,000 feet of white massive limestone. So far as known, the formation is exposed only on the southern border of New Mexico. It has suffered enormous erosion, and has been entirely removed from the central New Mexican area, over which it no doubt at one time extended. The extensive faunas which it carries have no known counterparts in the Kansan section. They are all younger than any of the described faunas of Carboniferous age in that district, yet older than the earliest Mesozoic faunas. The greatest development of the formation is found in the Guadalupe Mountains, in southeastern New Mexico, which form the western border of the broad Pecos valley. Fossils were described from this locality by Shumard more than half a century ago. Nothing more was known of them until quite recently, when Girty identified a large number of Shumard's species from this place and many others. The relationships of the formation with the other parts of the Carboniferous section of New Mexico have never been known until quite lately.

Along the east slope of the Guadalupe range the Carboniferous Red Beds, or Cimarronian series, appear to overlie the white limestone series in marked unconformity. Its position in the Kansas section probably is marked by a hiatus at the bottom of the Cimarronian beds of that region.

The great fault-scarp at Guadalupe Point presents a sheer precipice of more than 3,000 feet in height. The lower 200 feet appear to be the uppermost dark limestone of the Maderan series (Hueco limestone of Richardson). Then follow 1,500 feet of light-colored, coarse-grained massive sandstone—the Eddy formation,¹ which extends northward through Eddy County, New Mexico. The white Capitan limestone forms the upper 1,000 feet.

The Carboniferous Red Beds of New Mexico appear to be the western extension of the Cimarronian series of central Kansas.

¹ Richardson's name of Delaware formation for this bed is preoccupied for a well-known Ohio formation.

They rest unconformably upon the older rocks and have the triassic Red Beds reposing in a very marked unconformable relations upon them.¹ The formation has a very wide geographic distribution, and is, for the most part, unfossiliferous.

The complete sequence of formations composing the New Mexican Carboniferous section may be tabulated as follows:²

		SERIES	FORMATIONS	ROCKS
CARBONIFEROUS SYSTEM	PERMIAN	Cimarronian	Moencopie —————? —————?	Shales Sandstones Shales
		Guadaloupan	Capitan Eddy	Limestones Sandstones
		Maderan	—————? —————? —————?	Limestones Limestones Limestones
	PENNSYLVANIAN	Manzanan	Mosca Coyote Montosa Sandia	Limestones Sandstones Limestones Shales
		Ladronesian	Alamito	Shales
		Socorran	Lake Valley Berenda	Limestones Limestones
	MISSISSIPPIAN			

¹*American Journal of Science* (4), Vol. XX (1905), pp. 423-29.

²The wavy lines represent unconformities.